THE PARTIAL SIMULATION OF WEIGHTLESSNESS IN WATER

H. von Diringshofen

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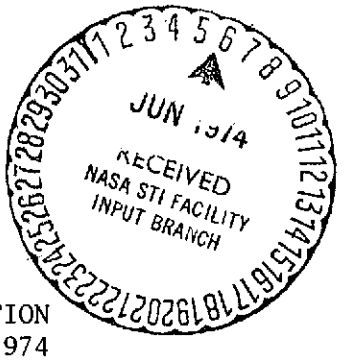

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16. Abstract

Author shows findings of balneology to be of interest in space research, and gives examples of application to study of weightlessness on earth.

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In recent years a large number of space medicine investigations have been carried out partially simulating weightlessness in water. /193*

In this way space medicine has established connections with bath healing, one of the oldest fields of medicine, which has been more and more supported scientifically by exact research in the last 50 years, predominantly in Europe.

Since balneology plays only a slight role in the United States, it is understandable that space medicine research on the mechanical effects of water on blood circulation and respiration has been given little notice there.

This has led to the fact that in partial simulation of weightlessness by immersion and submersion of the subject in water many effects have been attributed to the buoyancy of the water where the hydrostatic pressure of the water is at least considerably distributed on the breast and abdomen area.

I was deeply involved with these effects of water bathing between 1948 and 1950 [1]. For this reason I feel justified in giving critical consideration to the partial simulation of weightlessness by immersion in water from this point of view.

It undoubtedly provides a possibility of holding people in a hypodynamic state of suspension by means of the buoyancy of the water, and this has some similarity to suspension under conditions of weightlessness, but with the otolith still completely subject to gravity.

In water the hemostatically conditioned differences in blood pressure in regions of the body below the heart level are equalized by the hydrostatic counterpressure of the water if the water reaches this level or if the air pressure in the air passages corresponds to the water pressure at the heart level when diving equipment is used. The latter is achieved through proper

*Numbers in the margin indicate pagination in the foreign text.

adjustment of the aqualung of the diving equipment or by means of other regula- /194
tors. In this case the hydrostatic conditions for circulation below this level are the same as in so-called halfbathing with the water at the level of the heart.

However, when a person is immersed deeper or completely submersed the water pressure above the rib cage is not everywhere the same as in the lungs, but only at the level of the water or in the level determined by the breathing apparatus (Figure 1).

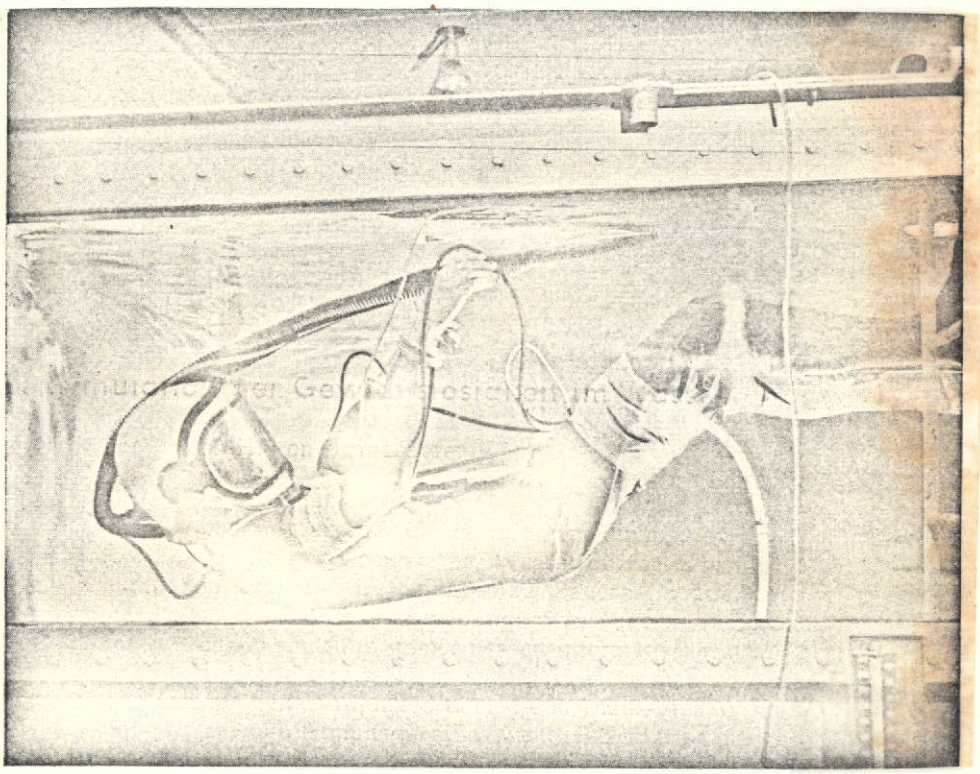

Figure 1. Subject in Partial Simulation of Weightlessness Suspended Underwater (The Arm and Leg Cuffs Serve for Temporary Venous Obstruction in the Extremities). Figure from Aerospace Medical Laboratories, Wright-Patterson AFB.

In this way local pressure differences, depending on a position in the water, can occur between the water pressure on the chest wall and the air pressure in the lungs, up to ±20 cm Wg, and these are not present in weightlessness.

In full bathing with the water level at the shoulders, a water pressure of about 20 cm Wg is exerted on the lower rib cage and transferred from the abdomen

to the diaphragm. In complete underwater diving this would correspond to an adjustment of breathing apparatus to the water pressure at shoulder level.

Modification of the water level by 20 cm produced changes of average lung volume of up to 700 ccm on a subject sitting upright in water.

The same results are to be expected in complete underwater diving if the level of pressure equilibrium between the lung air pressure and water pressure is displaced 20 cm.

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In contradistinction to the halfbath with the water at the level of the heart, the hemostatically conditioned blood pressure increases below the heart are overcompensated for in the full bath, i.e., with equilibrium of water pressure and air pressure in the lungs at the shoulder level or at the level of the breastbone in an inclined position.

In this way the point of indifference between the flow of liquid from blood into the tissue and returned to the blood, thus between filtration and resorption, it is shifted in the capillary area in the venous direction, having an increased water resorption and thus increased diuresis as a consequence which must be considered in partial simulation of weightlessness in water.

It seems to me that consideration of the pressure difference on both sides of the diaphragm is particularly important for the correct interpretation of the effects of partial simulation of weightlessness in water, because it can have a considerable effect upon the blood pressure in the vena cava in the vicinity of the heart.

On the basis of pressure measurements in the cubital vein in the water bath by Schott [2], Krueger and Budelmann [3] and my own former doctoral candidate Keller [4], we must contend with an increase of venous heart-filling pressure of about 15 cm Wg in the full bath and by +12 cm Wg in the three-quarter bath, reduced by perhaps 3 cm Wg by an increase in interpleural pressure. These are significant increases in pressure for the venous filling of the heart. They explain why patients suffering from severe myocardial damage react poorly to full and three-quarter baths, as well as the roentgenkymographic findings in

healthy subjects by Eckert and Boehme [5] from the Institute for Physical Therapy of the University of Munich. In the full bath the latter found an expansion of the transverse diameter of the heart image, particularly to the right, by an average of 8 cm, and symptoms of tight feelings similar to those found in extreme myocardial damage.

Naturally the circulatory controls in healthy people are able to regulate these water baths effects through parasympathetic adjustment that the heart volume per minute is only increased at the beginning, certainly involving the Jarisch-Bezold effect released by the pressure increase in the right vestibule and ventricle[1].

The parasympathetic adjustment through floating in water should be treated separately here. Its cause is the reduction of sympathicotonicity as a result of hypodynamics in the bath, which is comparable to hypodynamics in weightlessness.

Therefore it is important for partial simulation of weightlessness in water for the purpose of producing corresponding hypodynamic conditions that, when floating underwater, the air pressure in the diver's helmet should deviate as little as possible from the water pressure at the heart level and the passage of the vena cava through the diaphragm.

Most favorable for this underwater is a horizontal position of the trunk.

When the trunk is vertical the level of pressure equilibrium between water pressure and air pressure in the lungs is more favorable for respiration at the level of the nipples. For blood pressure in the vena cava this would approximately correspond to the effect of a three-quarter bath.

In conclusion I would also like to comment briefly on the effects of hypodynamics on a subject floating underwater for 6 hours in regard to circulatory controls, investigated directly by blood pressure measurement from a tilting table and changing from the horizontal to the vertical position.

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[1]Such circulatory controls are understood even better after the reports of Wezler and of Reindell at the Congress of the German Society for Internal Medicine in 1964 on the active regulation of the diastolic tonicity of the heart.

These tests by Graveline [6] et al., in the Biomedical Laboratory, Wright /196
Patterson Air Force Base, Ohio, were used to test the usefulness of circulatory control training through rhythmical blocking of venous reverse flow from arms and legs in respect to the increased tendency to orthostatic collapse to be expected in long term weightlessness. Every 2 minutes the venous reverse flow was obstructed for 1 minute by means of inflatable rubber cuffs.

Figure 2 shows the course of blood pressure with such tilting table tests after 6 hours floating in water, on the right without such circulatory control training and on the left with such training.

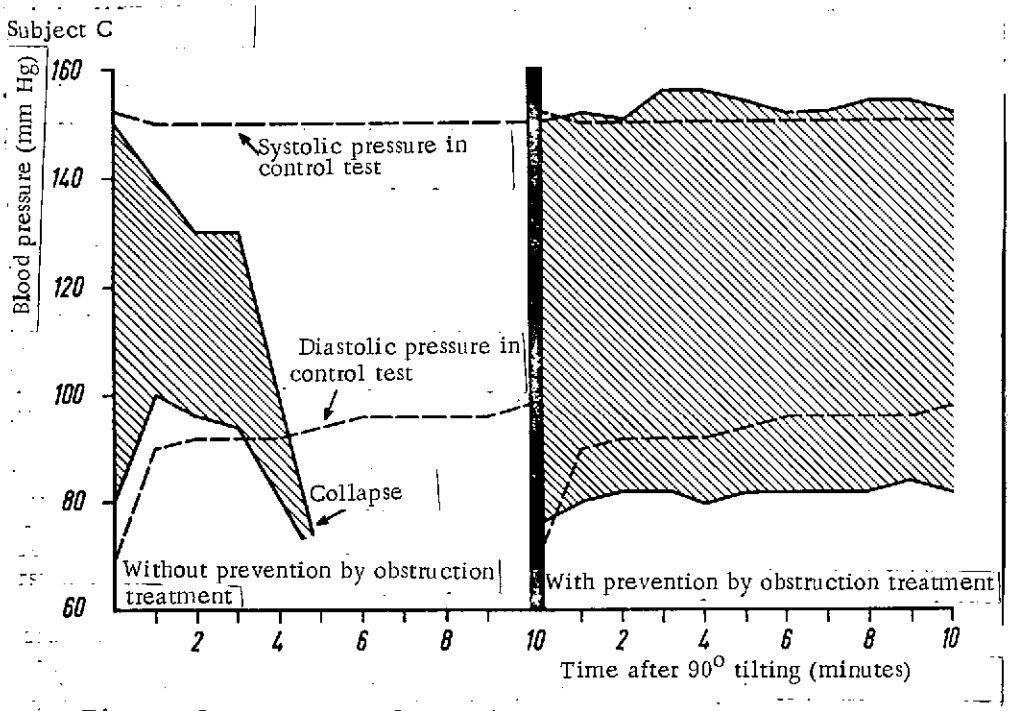

Figure 2. Course of Blood Pressure in a Tilting Table Test by Graveline et al., After 6 Hours Floating Underwater.
Left without and right with circulatory control training in water. The dashes indicate the course of blood pressure in the control test without being in water. (From *Aerospace Medicine*, Volume 11, p. 1010, 1963).

It is already known that the tendency to orthostatic collapse is also raised by hypodynamics after strict bed rest. For tests of this type bed rest has the advantage of doing away with the hydrostatic side effects of submersion in water on circulation and respiration, but the disadvantage of missing weight neutralization caused by buoyancy in water. Because of the simplicity of strict

bed rest this advantage can predominate for the production of hypodynamic conditions.

My remarks have been intended to show that in partial simulation of weightlessness in water space medicine is also connected with balneology, the oldest area of the healing arts, and that the results of balenological research can be important for the evaluation of such space medicine research.

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